Screening-Level Ecological Risk Assessment Approaches for Quantifying Lead Ammunition Ingestion and Adverse Effects in Birds

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OBJECTIVE

Propose a standard California-wide screening-level ecological risk assessment approach for quantifying the potential risk posed by lead ammunition at former skeet and firing ranges.

INTRODUCTION

The deleterious effects of wildlife ingestion of Pb shot or bullet fragments have been documented over many years and in numerous scientific studies (Rattner et al. 2008). Despite this fact, many ecological risk assessments submitted for regulatory review in the State of California do not consider the Pb particle ingestion pathway, particularly those that assess former or abandoned skeet and firing ranges.

In this poster presentation we propose methods for measuring and quantifying the degree of Pb particle contamination in soil that would be available for incidental or purposeful (grit) ingestion by birds, and select and provide examples of simple screening-level approaches for quantifying potential ecological risks. In the context of ecological risk, our method review, analyses, and assessment approach make the following assumptions that (1) birds are the most likely species to incidentally or purposefully ingest Pb particles, (2) birds are as or more susceptible to the toxic effects of Pb particles in the environment than other species, and (3) Pb particles are distributed within surface soils or sediments and available for ingestion. While it is possible for a variety of organisms (e.g., amphibians, reptiles, mammals) to potentially ingest Pb particles in the environment, we considered the foraging and grit ingestion behaviors of birds as placing them at greater risk than other species.

METHODS

Grit ingestion models were evaluated for three surface-feeding terrestrial (i.e., dove, raven) and wetland-associated birds (i.e., probing, dabbling, or grazing species, such as mallard) and one diving species (i.e., surf scoter).

Peddicord and LaKind Model (2000)

Common Raven (© 2007 Stephen Dowlan)

Dove (Game and Fish)

Mallard (DFG)

$$P = S \times P_s + (1 - S) P_o$$

$$P_t = 1 - (1 - P)^N$$

P = Probability that a single ingested particle will be a Pb shot
P_t = Probability of ingesting $\geq$ 1 Pb shot (0.5 to 2.8 mm dia.) in a lifetime
P_s = Fraction of grit-sized particles onsite that is Pb shot
P_o = Fraction of grit-sized particles offsite that is Pb shot
S = Fraction of foraging time that a bird spends on the site (S=1, assumed 100% site-use)
$N = Y \cdot (D_e / D_p)$

Where,
N = Particles selected/retained in the gizzard in a lifetime
Y = Number of years a bird lives
D_e = Number of days per year that a bird forages in the area (assumed 365-days for all 3 birds)
D_p = Retention time for a shot in the gizzard (days)

Table 1. Input Values for the Peddicord and LaKind Model

Parmeters	Receptor	Value	Reference
Average lifespan (Y)[a]	Raven	13.3-yrs	Clapp et al. 1983
	Dove	1.53-yrs	Leopold and Dendon, 1993
	Mallard	1.8-yrs	Drilling et al. 2002
Shot retention time (D_p)	Raven	6-d[b]	--
	Dove	6-d	Guy et al. 2004
	Mallard	21-d	Chasko et al. 1984

[a] All life spans are from wild birds, representing mean longevity.
[b] Assumed the same as dove.

The Binomial Probability Model (US Navy, 2004) for Alameda Point Skeet Range

Surf Scoter

$$P(r) = \frac{n!}{r!(n-r)!} p^r (1-p)^{n-r}$$

n = number of dives/dabs for grit over blood lead retention time; based on number of foraging dives per day and proportion of daily foraging dives for grit
r = # of Pb shot ingested, selected threshold
P = probability of encountering Pb shot; based on relative abundance of Pb shot and grit within 0.5 – 4 mm dia. size range in sediment

Table 2. Input Values for the Binomial Probability Model

Input	Value	Explanation
r	1, 2, 5, or 10	# of Pb shot ingested, selected threshold
p	variable	Probability of ingesting one pellet per probing event; based on relative abundance of Pb shot and grit within 0.5 – 4 mm range in sediment (US Navy, 2004)
f	0.422	Highest site mean foraging time for scaup across 5 sites within San Francisco Bay (as fraction of day) (Poulton et al., 2002)
d	3989 dives/day	2.77 dives/min based on mean dive duration of scaup of 21.6 sec in San Francisco Bay (Poulton et al., 2002)
α	0.42	Maximum percent grit in stomach of a surf scoter (Vermeer, 1981) is assumed to represent fraction of foraging dives to acquire grit.
g	707 dives for grit/day	$g_{(grit\ dives/day)} = d_{(dives/day)} \times f_{(fraction\ day\ for\ foraging)} \times \alpha_{(fraction\ dives\ for\ grit)}$
i	49-days	Maximum amount of time lead ingested as shot estimated to remain in the gizzard, blood, and/or soft tissues (Mautino and Bell, 1986)
n	34,643 dives for grit over 49-days	$n = g \times i \times SUF$, assuming 100% site-use

Determining The Density, Size, Occurrence Of Pb Particles In The Environment

- Sampling designs for outdoor shooting ranges should be appropriate for estimating the mean of positively skewed distributions.
- Soil sample locations should be selected using random sampling methods that provide adequate coverage of the site, particularly in the shot fall zone.
- Sampling depths in surface soils should be top 1 inch to assess current exposure scenarios. Record volume and weight of sample. For sediment samples, consider the probing depths of avian receptors evaluated.
- Soil samples should be processed using several different size sieves. A 4.75 mm (No. 4) sieve should be used to initially process the sample to remove bulk material. If terrestrial birds or the mallard are the selected receptors, material retained between 0.5 – 2.8 mm sieves (No. 35 and No. 7) represents grit sizes utilized by these species. The grit-size range for scoter is reportedly much wider, thus material retained between 0.5 – 4 mm sieves (No. 35 and No. 5) would need to be analyzed. These applicable fractions are then sent to the lab for Pb and grit count analysis.

How Many Pb Particles Must Be Ingested Before Toxic Effects Are Manifested?

- Toxicity dependant on species and number/size of particles ingested.
- For purposes of screening-level risk assessment and to be protective of all bird species, we propose that the probability of a bird ingesting one lead particle (e.g., sized between 0.5 and 2.8 mm in diameter) be predicted

RESULTS

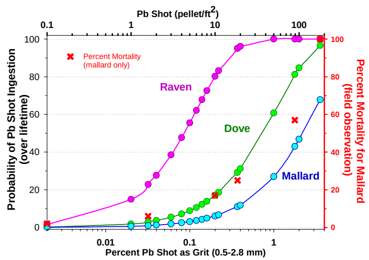


Figure 1. Probability of Pb Shot Ingestion by Birds Assuming100% Site-Use

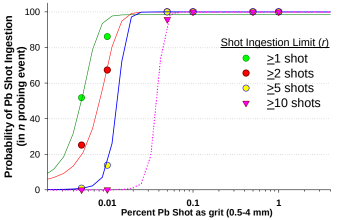
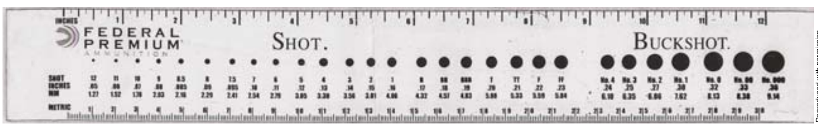


Figure 2. Probability of Pb Shot Ingestion of a Scoter in *n* Probing Event for Grit by Shot Ingestion Limit

Table 3. Pellet Number and Probability of Bird Ingesting 1 Pb Shot over Its Lifetime

Number of Pb Shots	Percent Grit as Pb Shot	Number of Particles Selected N=Y·(De/Dp)			Probability (P_t)[c,d]			Mallard Percent Mortality
(shots/ft^2)[a,e]	(P_s)[b]	Raven	Dove	Mallard	Raven	Dove	Mallard	from field studies[e]
0	0%	809	93	31	0	0	0	0%
0.1	0.002%	809	93	31	1.6%	0.2%	0.063%	2%
1	0.020%	809	93	31	15%	1.8%	0.62%	
1.6	0.032%	809	93	31	23%	2.9%	1.0%	6%
2	0.040%	809	93	31	28%	3.7%	1.2%	
3	0.060%	809	93	31	38%	5.4%	1.9%	
4	0.080%	809	93	31	48%	7.2%	2.5%	
5	0.10%	809	93	31	55%	8.9%	3.1%	
6	0.12%	809	93	31	62%	11%	3.7%	
7	0.14%	809	93	31	68%	12%	4.3%	
8	0.16%	809	93	31	73%	14%	4.9%	
10	0.20%	809	93	31	80%	17%	6.1%	17%
11	0.22%	809	93	31	83%	19%	6.7%	
18.5	0.37%	809	93	31	95%	29%	11%	25%
20	0.40%	809	93	31	96%	31%	12%	
50	1.0%	809	93	31	100%	61%	27%	
89	1.8%	809	93	31	100%	81%	43%	57%
100	2.0%	809	93	31	100%	85%	47%	
178	3.6%	809	93	31	100%	97%	68%	100%

[a] Refers to shots in the 2.8-mm to 0.5-mm size class, with depth of 1". We assumed this size range overlaps preferences of mallard, dove, and raven.
[b] Based a regression model that estimates percent lead shot from lead shot density (shot/ft^2). Data obtained from Range 17, Patuxent Research Range (USFWS/USEPA, 2004).
Percent lead shot = 0.0002·(shot/ft^2), R^2=0.843, P=0.0013
[c] Receptor is assumed to be a year-round resident species with 100% site-use (SUF=1).
[d] Defined as probability that the bird will ingest $\geq$1 Pb shot in its lifetime.
[e] Field studies on mallard with these bolded Pb shot densities were conducted in wetlands. Mortality was obsered in the highest treatment group average within 22.5-d and up to 94-d for lower treatment groups. Colored values refer to different studies: Irwin and Karstad, 1972; Rocke et al., 1997.



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CONCLUSIONS

- The Peddicord and LaKind Model was evaluated for a birds that select grit within the 0.5 to 2.8 mm range of preference established in the literature. The model demonstrates that longer-lived birds with short grit retention times are most at risk (Table 3 and Figure 1). This model is recommended for non-diving grit-eating birds
- The Binomial Probability Model was assessed for scoter, a diving duck. Figure 2 shows that (1) the margin for ingesting greater than 1, 2, or 10 Pb shot is very narrow (i.e., 0.005-0.007% Pb shot as grit), suggesting that scoter is at higher risk than terrestrial species from a high grit probing frequency, and (2) when Pb shot abundance is >0.01% in sediment, the chance of scoter ingesting Pb from repeated dives for grit approaches 100%. This model is recommended for diving seabirds.
- Both models suggest Pb shot should be measured as abundance relative to other natural particles (expressed as percent Pb shot) in the preferred grit-size range.
- Table 3 compares the probability (% chance) that mallard will consume Pb shot versus mallard mortality measured in a controlled field Pb shot exposure study. The comparison shows that as Pb shot becomes increasingly abundant relative to soil grit, the rate at which the mortality increases is similar to the rate at which the probability of lead ingestion increases (Figure 1).
- For screening-level ERA purposes, we suggest that if ingestible Pb particle counts in soil or sediment generate a higher than 1% probability of ingestion of one particle, then further ecological assessment (i.e., Tier II or Validation Study) is recommended. Factors that can be considered in Tier II include site fidelity and the number of lead particles (i.e., possibly greater than 1) required to cause various degrees of adverse effects.

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